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WADC TECHNICAL REPORT 54-570

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THE EFFECT OF FABRIC STRUCTURE ON THE FRICTIONAL FUSION OF PARACHUTE MATERIALS

VASILIS LAVRAKAS

LOWELL TECHNOLOGICAL INSTITUTE
RESEARCH FOUNDATION

AUGUST 1955

WRIGHT AIR DEVELOPMENT CENTER

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WRIGHT AIR DEVELOPMENT CENTER
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FOREWORD

This report was prepared by the Lowell Technological Institute of Massachusetts Research Foundation under USAF Contract No. AF 18(600)-136. The contract was initiated under Project No. 7320 "Air Force Textile Materials", Task No. 73201 "Textile Materials for Parachutes", formerly RDO 612-12, "Textiles for High Speed Parachutes", and was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with Mr. Jack Ross acting as project engineer.

The author wishes to express his gratitude for the cooperation in this project of the following individuals: Mr. Adolph Katz, Technical Director of the Lowell Technological Institute Research Foundation; Mr. Albert T. Woidzik and Prof. Jacob K. Frederick, Jr., members of the faculty of the Lowell Technological Institute.

This report is one of a series which have been issued on a study of the effects of lubricants and fabric structure on the frictional and fusional properties of parachute cloth and line.

This report covers work conducted from March 1954 to March 1955.

ABSTRACT

The effect of fabric structure, yarn twist, calendering, and fabric weight on the resistance to fusion of parachute cloth has been studied. A belt friction apparatus, used in lubrication investigations, has also been utilized in this study.

The parameters of fabric structure, yarn twist, calendering, and fabric weight have been found to be significant in the resistance of parachute cloth to friction.

The results of this study are as follows:

1. The best fabric structure was cloth made according to MIL-C-7020, Type I.
2. Calendered cloth was superior to non-calendered.
3. Low yarn twist and fabric weight appeared to impart higher resistance to fusion than higher twist and weight.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

M. R. WHITMORE
Technical Director
Materials Laboratory
Directorate of Research

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INTRODUCTION

The problem of "line burns" appearing on the panels of a nylon parachute during its deployment has been extremely serious. In WADC TR 54-323, Parts 1 and 2 (1,2), work has been done to investigate the effect of lubricants on the fusion at high speeds of parachute materials. It was found that lubricants were capable of protecting the nylon from fusing under relatively severe conditions of speed and load.

However, in addition to a study of lubricants, it was desirable to complete this investigation with a study of the effect of fabric structure and weight, and yarn twist upon the fusion of parachute materials. From the results obtained, it would be possible to specify optimum conditions in the construction of canopy cloth.

APPARATUS

The apparatus used for these experiments is the same as that described in Reference 1. A diagrammatic sketch of the basic parts of the apparatus as well as a photograph are presented in Figures 1 and 2, respectively. The principal element of the apparatus is a revolving pulley (C) around which the parachute cloth is wrapped. The shroud line (F) is then wrapped around the cloth on the pulley for the desired angle of contact. Frictional force at any speed (25, 36, 52, and 75 ft/sec) is measured by means of a strain gauge. Fusion of the parachute materials during sliding is detected by an instantaneous increase in frictional force registered on the recorder, as well as by the ripping of the cloth.

METHOD OF TESTING

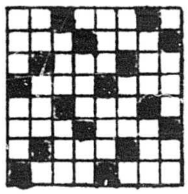
The method of testing used in this study was basically the same as described in WADC TR 54-323, Parts 1 and 2. However, some changes from the previous procedure were made and are as follows: the time of running at any given load was changed from 1.5 minutes to 10 seconds, as well as allowing exactly 30 seconds to pass after each run of 10 seconds. The advantages in this method were found to be a saving of time and a somewhat greater accuracy in test results. In addition, the angle of wrap of the parachute line was decreased from 360° to 180°. This was done to permit a greater range in fusion loads to be attained. Finally, fusion was always approached in increments of 50 gm slack tension beginning with an initial slack tension of 52 gm. The slack tension at which fusion occurred is referred to as the fusion load (FL), and is assumed to be a direct measure of the ability of a parachute material to resist fusion.

Parachute suspension cord (MIL-C-5040, Type III) lubricated with Alkaterge C, was always run against the fabric structure to be tested at percentage pickups* ranging from six to eight percent. A control, using MIL-C-7020, Type I, was used to check the effects of aging upon the lubricant, as well as to insure that dipping of a fresh length of line which invariably resulted in a different percentage pickup would not give different results from previous runs.

MATERIALS USED

Six samples of basic weaves were woven at the Lowell Technological Institute Research Foundation. These were as follows:

1. Plain weave
2. Twill, 2/2
3. Twill, 2/2
4. Twill, 3/1
5. Basket, 2 x 2
6. Crowfoot, Satin (See below)



CROWFOOT SATIN WEAVE

The yarn used in these six fabrics was Type 200 commercial first quality nylon. The yarn (10 filament, 30 denier, 7 turns per inch of Z twist) was sized. The filling yarns used were of a 1/2 turn of Z twist per inch, but were similar to the warp yarns in all other respects.

$$\text{* Percent Pickup} = \frac{\text{Weight of Lubricated Cord} - \text{Weight of Scoured Cord}}{\text{Weight of Scoured Cord}} \times 100$$

Forty samples of calendered and non-calendered fabrics containing variations of twist in the warp and filling yarns were obtained from the Fabric Research Laboratories of Boston, Massachusetts. These samples were from a specialized series of fabrics prepared by Fabric Research Laboratories under Air Force Contract No. AF 33(616)-387. All the fabrics are constructed of 30 denier, type 200 nylon. The thread count is 120 by 120, and the fabric is constructed as a simulated Rip Stop, Type I. Only ten of these were used as a sufficient representation of changes in warp and filling direction, and both directions together were obtained by the use of these ten.

The forty fabrics received from Fabric Research Laboratories reflected two finishing procedures since twenty were calendered and the other twenty were not calendered.

The following system of notation was used to identify the samples: R signifies rip stop parachute canopy cloth; the next number is the nominal number of turns per inch of the warp yarns; the next letter, either C or N, indicates the fabric is calendered or non-calendered; and the final number is the nominal turns per inch of the filling yarns. For example, a fabric identified as R$\frac{1}{2}$C5 is a canopy fabric of rip stop construction with warp yarns having $\frac{1}{2}$ T.P.I., calendered, and with filling yarns having 5 T.P.I.

Samples of the following materials were supplied through the courtesy of the Wright Air Development Center, Wright-Patterson Air Force Base, Ohio:

1. MIL-C-7020, Type I and II
2. MIL-C-7020, Type I and II (OD Color)
3. Dacron, comparable to MIL-C-7020, Type II
4. MIL-C-8021, Type I and II

RESULTS AND DISCUSSION

The experimental results concerning fusion load (FL), picks/in., ends/in., variance, and fabric weight of all fabrics are presented in Table 1.

The Effect of Twist on Fusion

Table 2 contains data on the effect of yarn twist upon fusion load.

The fabric R$\frac{1}{2}$C$\frac{1}{2}$ was taken as a basis for comparison for all fabrics in this group (calendered). Statistical tests (t test at the 5% level) indicated that a significant difference existed between the means of fusion loads of R$\frac{1}{2}$C$\frac{1}{2}$ (217 gm) and R30C30 (182 gm). The fabric with the lowest twist has a higher fusion load than the fabric with the highest twist. In fact, R$\frac{1}{2}$C$\frac{1}{2}$ was the best fabric of all fabrics tested in the calendered and non-calendered group.

The same effect of twist is observed in the non-calendered group; i. e., as twist increased for $R\frac{1}{2}N\frac{1}{2}$ (FL = 187 gm) and R30N30 (FL = 147 gm), the fusion load decreases.

It was also observed that intermediate values of twist (R20C20 and R20N20) have values for fusion load roughly midway between the extreme values. This would indicate that a change in twist produced a gradual change in fusion load.

The effect of increasing twist in warp and in filling yarns was also studied (Table 2). An insufficient number was studied. Therefore, no definite conclusions were drawn concerning fusion load. However, the trend, as the twist increases in the warp yarns, indicated that no significant decrease occurred in fusion load for either calendered or non-calendered materials.

In the calendered sample, as the twist of the filling yarn increased, results indicated that the fusion load decreased significantly. But for the non-calendered sample the decrease is not statistically significant. Consequently, further testing with a greater number of tests, as well as samples, would have to be done to establish whether or not a real difference exists in the means.

The Effect of Calendering on Fusion Load

Significant differences are observed between calendered and non-calendered fabrics (Table 2). The calendered fabrics, with one exception, have higher values for fusion load than the non-calendered fabrics. Thus $R\frac{1}{2}C\frac{1}{2}$ with a fusion load of 217 gm is better than $R\frac{1}{2}N\frac{1}{2}$ with a fusion load of 187 gm. The same trend is observed for the fabrics with the highest twist; R30C30 is superior to R30N30.

It may be concluded that calendering appears to have a beneficial influence upon the resistance of a fabric to fusion.

Fabric Structures and Fusion Load

Table 3 contains in two groups those fabrics which are statistically different from those which are not, using $R\frac{1}{2}C\frac{1}{2}$ as the basis for comparison. Group I has fabric structures whose ability to resist fusion is high. Group II has fabric structures whose ability to resist fusion is low.

The best fabric structure, as measured by its possessing the highest fusion load, was MIL-C-7020, Type I.

Fabric Weight and Fusion Load

The data obtained on the effect of fabric weight on fusion load are presented in Table 4. Only in the case of two fabrics, 2a and 2b, and 3a and 3b, is the effect of increasing weight on fusion load statistically different. In these two cases, as the weight increases the fusion load decreases.

It is also interesting to observe that the overall trend of decreasing fusion load with increasing fabric weight appears to favor the hypothesis that fusion load is dependent upon fabric weight. However, as an insufficient range in fabric weight was studied, no definite conclusions can be given.

SUMMARY

1. Fabrics made of low twist yarns are more resistant to fusion than fabrics with high twists.

2. Calendered fabrics have higher fusion loads than non-calendered.

3. Fabric structure also affects fusion load as significant differences were obtained among many of the fabrics studied (see Table 2). The best fabric in resistance to fusion was MIL-C-7020, Type I.

4. Fabric weight may also be significant as the trend in fusion load as fabric weight varies appears to favor the hypothesis that fusion load is dependent on fabric weight.

BIBLIOGRAPHY

1. Lavrakas, V. and Katz, A.: The Effect of Surface Finishes on Friction and Fusion of Parachute Cloth and Line; WADC Technical Report 54-323, Part 1.

2. Ibid, Part 2

TECHNICAL TERMS AND DEFINITIONS

Angle of Wrap - The angle of contact of the parachute cord with the revolving pulley.

Fusion Load (FL) - The slack tension, expressed in grams, of the parachute cord when fusion occurs between parachute cord and line.

$$\text{Percent Pickup} = \frac{\text{Weight of Lubricated Cord} - \text{Weight of Scoured Cord}}{\text{Weight of Scoured Cord}} \times 100$$

TABLE 1

Statistical and Experimental Data on Fabric Structures

LTIRF Fabrics

Fabrics	No. of Tests	s^2	FL gm.	Picks/in.	Ends/in.	Weight oz/sq yd
1a* (Plain)	10	762	167	120.0	120.0	1.07
2a (Twill, 1/2)	10	1025	187	124.6	121.2	1.05
3a (Twill, 2/2)	10	1000	212	121.0	118.0	1.02
4a (Twill, 1/3)	10	1025	187	120.4	120.4	0.99
5a (Basket, 2 x 2)	10	500	202	119.6	117.0	1.01
6a (Crowfoot, Satin)	10	400	162	118.8	120.2	1.06
1b*	10	525	187	145.0	125.6	1.13
2b	10	400	162	145.6	121.0	1.12
3b	10	625	177	147.8	120.4	1.13
4b	10	525	167	147.4	121.6	1.12
5b	10	600	182	149.4	118.2	1.14
6b	10	400	162	148.4	120.8	1.15

USAF Fabrics

Fabrics	No. of Tests	s^2	FL gm.	Picks/in.	Ends/in.	Weight oz/sq yd
MIL-C-7020, I	10	1459	216	122.4	117.2	1.06
MIL-C-7020, II	10	355	142	126.4	74.6	1.49
Dacron, Comparable to MIL-C-7020, Type II	10	1439	152	72.8	136.4	1.71
MIL-C-8021, I	10	225	157	55.2	55.4	3.42
MIL-C-8021, II	10	400	142	46.6	60.2	7.04
MIL-C-7020, I (OD)	10	1225	207	123.4	117.8	1.07
MIL-C-7020, II (OD)	10	600	182	127.8	80.0	1.6

* (a samples differ from b samples in that a samples have lower picks/in.and weight while ends/in.for both a and b remain essentially constant.)

TABLE 1 (Continued)

Fabric Research Laboratories Fabrics

Fabrics	No. of Tests	s^2	FL gm.	Picks/in.	Ends/in.	Weight oz/sq yd
R½C½	10	520	217	127.2	120.4	1.07
R½C30	10	600	182	122.6	119.2	1.08
R20C20	10	1225	196	118.8	120.2	1.00
R30C½	10	2025	217	119.8	121.0	1.05
R30C30	10	600	182	116.8	120.0	1.03
R½N½	10	566	187	126.6	119.0	1.03
R½N30	10	525	167	121.4	119.0	1.05
R20N20	10	400	162	117.2	120.0	1.04
R30N½	10	600	172	119.8	120.8	1.00
R30N30	10	225	147	117.2	120.0	0.96

TABLE 2

The Effect of Yarn Twist on Fusion Load

Part I

The Effect of Increasing Twist in Warp and Filling Yarns

Fabric	Calendered FL, gm	Δ	Fabric	Non-Calendered FL, gm	Δ
R½C½	217		R½N½	187	
R20C20	196	21	R20N20	162	25
R30C30	182	35	R30N30	147	40

Part II

The Effect of Increasing Twist in Either Warp or Filling Yarns

Fabric	FL, gm	Δ	Fabric	FL, gm	Δ
R½C½	217		R½N½	187	
R30C½	217	0	R30N½	172	15
R½C30	182	35	R½N30	167	20

TABLE 3

Fabric Structures and Fusion Load

Group I

Fabric	FL, gm
MIL-C-7020, Type I	216
Twill, 2/2, 3a	212
MIL-C-7020, Type I (OD)	207
Basket, 2 x 2, 5a	202
Twill, 1/3, 4a	187
Twill, 1/2, 2a	187

Group II

Fabric	FL, gm
Plain, 1b	187
(Basket, 2/2, 5b	182
(MIL-C-7020, Type II (OD)	182
Twill, 2/2, 3b	177
Twill, 1/3, 4b	167
Plain, 1a	166
(Crowfoot, Satin, 6a	162
(Twill, 1/2, 2b	162
(Crowfoot, Satin, 6b	162
MIL-C-8021, Type I	157
Dacron, Type II	152
(MIL-C-7020, Type II	142
(MIL-C-8021, Type II	142

TABLE 4

The Effect of Fabric Weight on Fusion Load

Fabric	A FL, gm	Fabric	B FL, gm	Δ = A-B	Weight Increase oz/sq yd	5% Level
1a	167	1b	187	-20	0.06	Not significant
2a	187	2b	162	+25	0.07	Significant
3a	212	3b	177	+35	0.11	Significant
4a	187	4b	167	+20	0.13	Not significant
5a	202	5b	182	+20	0.13	Not significant
6a	162	6b	162	0	0.09	Not significant

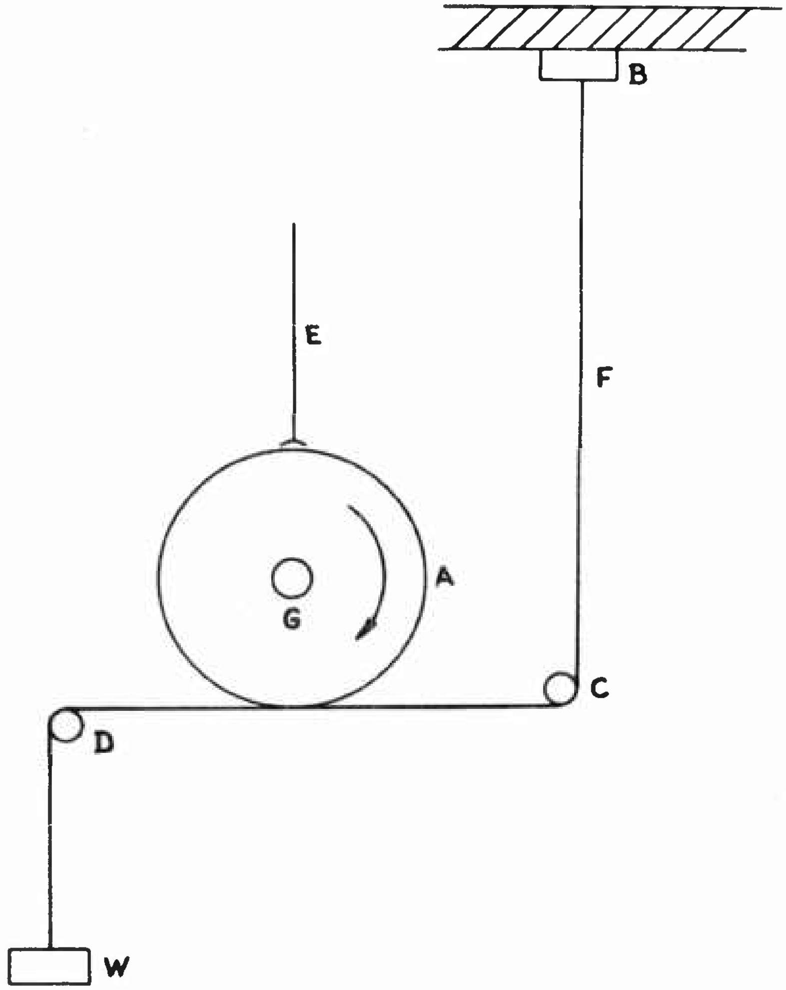


FIGURE I. DIAGRAM OF HIGH SPEED FRICTION APPARATUS.

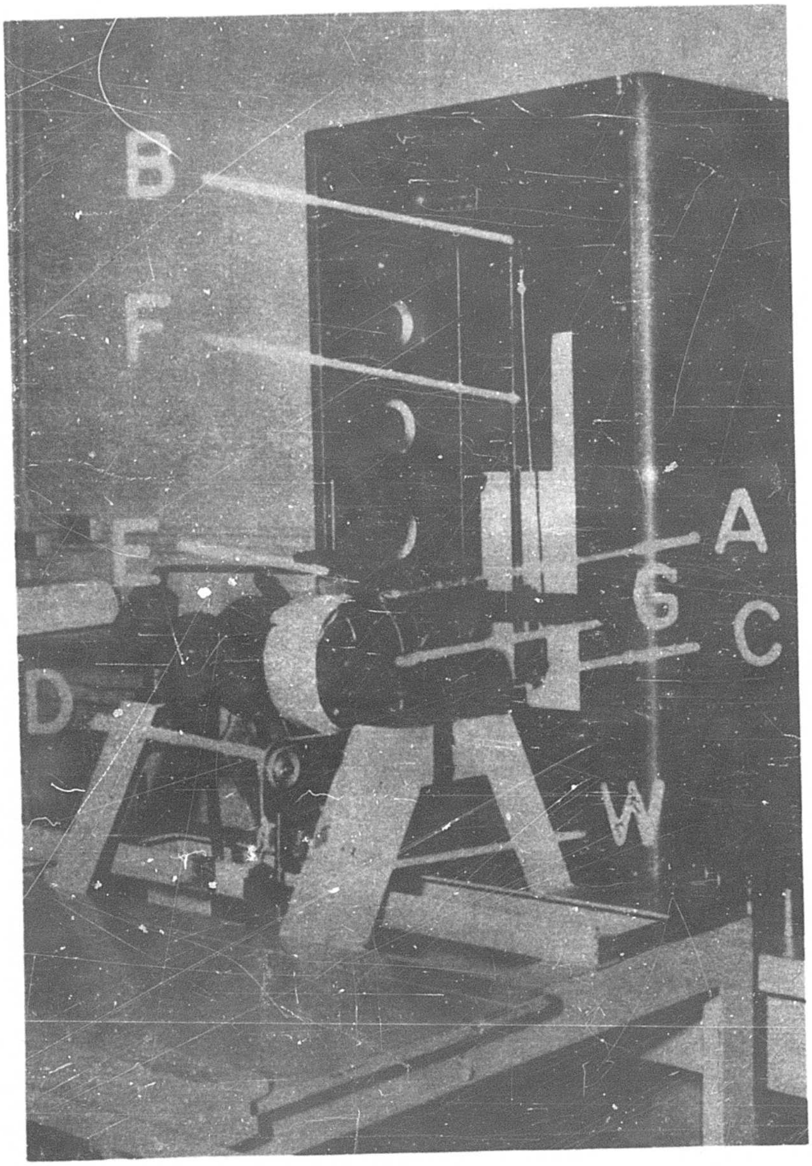


FIGURE 2

LTIRF High Speed Friction Apparatus

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